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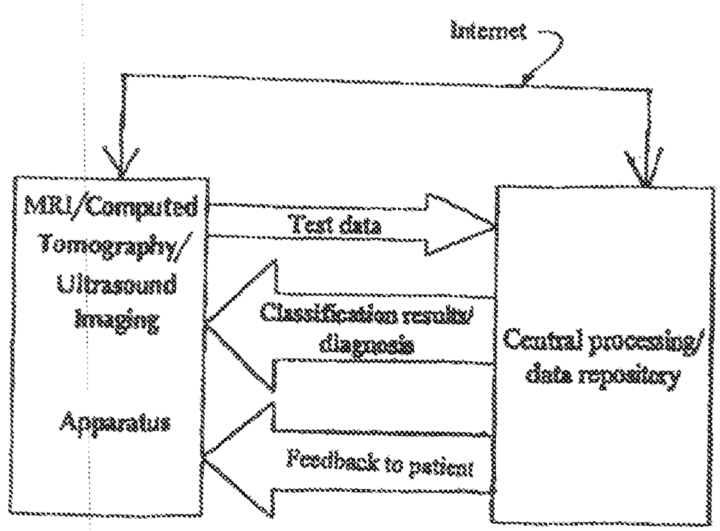
(54) **AUTOINTERPRETATION DES TESTS DE DIAGNOSTIC MEDICAL PAR TELEMEDECINE**

(54) **AUTOINTERPRETATION OF MEDICAL DIAGNOSTIC TESTS VIA TELEMEDICINE**



(57) A method and an apparatus for the performance and autointerpretation via the Internet, or other telemetric vehicle, of medical diagnostic imaging tests, such as magnetic resonance imaging, computed tomography, and ultrasound. Such testing soul instantaneous autointerpretation of imaging tests utilizing a local imaging device, via telemedicine, such as via the Internet, allows the system to be employed one a world-wide basis.

ABSTRACT OF THE DISCLOSURE

A method and an apparatus for the performance and autointerpretation via the Internet, or other telemetric vehicle, of medical diagnostic imaging tests, such as magnetic resonance imaging, computed tomography, and ultrasound. Such testing and instantaneous autointerpretation of imaging tests utilizing a local imaging device, via telemedicine, such as via the Internet, allows the system to be employed on a world-wide basis.

TITLE OF THE INVENTION

Autointerpretation of Medical Diagnostic Tests via Telemedicine

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part patent application of co-pending U.S. Patent Application Serial No. 09/203,729, filed on 12/02/98, and entitled "Visual Field Testing Via Telemedicine", which is a continuation-in-part of co-pending U.S. Patent Application Serial No. 09/179,112, filed on 10/26/98, and entitled "Automated Visual Function Testing Via Telemedicine", which is a continuation-in-part of U.S. Patent Application Serial No 08/700,754, filed on 7/31/96, now U. S. Pat. No. 5,864,384, and U. S. Patent Application No. 08/864,331, filed on 5/28/97, now U. S. Pat. No. 5,898,474. This application also relies upon the priority of U. S. Provisional Patent Application Serial No. 60/160,059, filed on 10/18/99, and entitled "Autointerpretation of Magnetic Resonance Imaging Utilizing Telemedicine", and U. S. Provisional Patent Application Serial No. 60/161,102, filed on 10/22/99, and entitled "Computed Tomography and Ultrasound Autointerpretation Utilizing Telemedicine". The parent applications, U.S. Patent Application Serial No. 09/203,729, and U.S. Patent Application Serial No. 09/179,112 claimed priority from U. S. Provisional Patent Application Serial No. 60/067,521, filed on 12/4/97; U. S. Provisional Patent Application Serial No. 60/089,817, filed on 6/19/98; and U. S. Provisional Patent Application Serial No. 60/090,214, filed on 6/22/98.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

BACKGROUND OF THE INVENTION

Field of the Invention - This invention is in the field of diagnostic tests used to provide images of portions of the body of a patient.

Background Art - The interpretation of magnetic resonance imaging (MRI), computed tomography (CT), and ultrasound diagnostic tests is challenging, even to

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experienced physicians and technicians. The quantity of information garnered by the newest generations of medical imaging devices is becoming truly gargantuan, and related software systems are expanding on an almost daily basis. The advent of three dimensional imaging has added to the complexity of the evaluation process. Multislice CT scanners, for instance, process patient volumes so quickly that they threaten to overwhelm diagnosticians with the hundreds of slices created in little more than half a minute.

Although greater diagnostic accuracy is rendered possible utilizing these new advanced systems, the likelihood of missing an important disease process lost in a veritable mountain of data increases as the voluminous data files explode in size. What is occurring is not only a burgeoning of already monstrously-large software programs, but an almost exponential increase in the power of new imaging technologies, resulting in vastly faster imaging speeds for multislice reconstructions. To be practical, these reconstructions must be done with great speed, which is possible only with massive computer power.

Currently known diagnostic systems typically require a physician or expert technician to select specific areas of interest for detailed analysis, and they typically require the use of very sophisticated data processing equipment. This limits the application of new evaluation methods to a relatively few locations, where the necessary equipment is available.

BRIEF SUMMARY OF THE INVENTION

The present invention, incorporating autointerpretation and telemedicine modalities, does not require a radiologist, or trained medical specialist, to select suspicious areas on the MRI, CT or ultrasound scan, as these are located automatically by the software system. The software analyzes the MRI, CT or ultrasound scan in its entirety, searching automatically for abnormalities and changes from the norm, or changes from previous MRI, CT or ultrasound tests, in addition to supplying, and analyzing changes in, the size, density, and even chemical composition of the tissue undergoing MRI, CT or ultrasound imaging. Serial MRI, CT or ultrasound scans can be

compared automatically over time to monitor any changes, thus documenting disease progression.

The present invention utilizes a neural network to automatically interpret the data gathered by the MRI, CT or ultrasound scan, and the neural network is continually updated to become increasingly more accurate as the data base enlarges. Alternatively, rule-based expert systems can also be utilized with the present invention. The data and diagnostic results are transmitted via the Internet. Use of the Internet and an automatic interpretive system, which is continuously trained, provides excellent interpretation capability in any part of the world, regardless of the experience level of the local radiologist. In fact, a technician trained in performing the MRI, CT or ultrasound scan is all that is required at the local MRI, CT or ultrasound imaging site, as the expertise is supplied, in effect, from a distant site via telemedicine. With the huge data base developed by a world-wide telemedicine system, leading international experts on MRI, CT or ultrasound imaging, and neurological and other diseases diagnosed by MRI, CT, or ultrasound modalities can be consulted to improve the accuracy of the entire system.

The novel features of this invention, as well as the invention itself, will be best understood from the attached drawings, taken along with the following description, in which similar reference characters refer to similar parts, and in which:

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 is a schematic diagram of the information flow in the system of the present invention; and

Figure 2 is a schematic diagram of the automatic interpretation portion of the system of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a telemedicine and autointerpretation system which will reduce errors in diagnosis related to diagnostic medical imaging, such as MRI, CT scans and ultrasound scans. The present invention is an integrated system for automated, computerized interpretation via the Internet of the test data parameters

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obtained during the performance of MRI, CT or ultrasound imaging. The data produced by the testing system are automatically reviewed and correlated with previously-determined patterns recognized to be "normal" or "abnormal," and clinical diagnoses for pathological conditions are thereby suggested to the clinician. As illustrated in Figure 1, telemedicine is utilized to receive test data from the patient and to transmit the test interpretation, including the suspected diagnosis, or diagnoses, and recommendations for further clinical correlation or for further ancillary tests. The telemedicine system is "intelligent," in that ongoing data accumulation and analyses thereof improve the computational model and provide, over time, increasingly more accurate identification of very subtle disease processes.

The present invention uses clustering algorithms, linear and non-linear mapping algorithms, and pattern recognition algorithms, either individually or as a combination thereof. A database of empirical, semi-empirical, or simulated test data is used to build a model of the MRI, CT or ultrasound test data. This model, when applied to previously unseen test results, is capable of automatically interpreting and classifying the test data in terms of the presence and severity of abnormal, or diseased, regions and states.

The data processing portion of the system provides not only the classification of the MRI, CT or ultrasound test data in terms of presence or absence of all disease, or any particular disease, such as brain tumor, stroke, congenital malformation, cardiac defect, breast cancer, but also may assign a probability of detection or a numerical value indicating the severity of the disease. This provides a tool for monitoring disease progression.

The automatic interpretation portion of the system, illustrated in Figure 2, may be a binary classification system, which will indicate the presence/absence of a particular disease, such as tumor, vascular malformation or disease, such as Alzheimer's disease, or a multi-class system, which will provide recognition and classification of a large variety of possible disease states, including, but not limited to, neurological tumors, cerebrovascular accidents and strokes, optic nerve disorders, compression syndromes of the optic nerve, the optic chiasm, or of the spinal column, demyelinating diseases, Alzheimer's disease, breast diseases, including breast carcinomas and other forms of

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breast cancer, also well as benign breast lesions, such as fibroadenoma, and also diseases of internal organs, such as of the liver, the spleen, the heart, or the pancreas, or of the extremities, such as osteosarcoma tumors, or injuries such as torn cartilage or bone damage.

The system can include an imbedded processing system forming an integral part of the MRI, CT or ultrasound testing apparatus. The entire testing process can be performed via long-distance transmission vehicles, such as, but not limited to, Internet or optical fiber, thus providing, telemetrically, essentially instantaneous autointerpretation. A central world-wide monitoring and data collection station or series of stations can link the system and provide multiweb-like integration. The Internet provides instantaneous, extremely affordable world-wide access. The telemedicine systems of the present invention are "intelligent," in that ongoing data accumulation and analyses thereof improve the computational model and provide, over time, increasingly more accurate identification of very subtle disease processes. Although neural network classification is preferred, other classification systems, such as multivariate analysis, linear regression, and statistical classifiers or discriminators, such as Bayesian classifiers, can be useful. Alternatively, a rule-based expert system is useful for comparison, and this is, therefore, within the scope of the present invention..

The interpretation system utilizes the results of imaging from MRI, CT or ultrasound scans, which are converted into numerical representations for data processing. Other inputs, resulting from standard pre-processing of the test data, such as any known history of the patient's disease process expressed in simple-to-use code, can also be employed by the autointerpretation system to aid in diagnostic accuracy. For instance, if a brain tumor is biopsy-proven to be a specific type of astrocytoma, this information is helpful in tracking serially the progression of this disease state. Inclusion of all available individual components of the MRI, CT or ultrasound imaging test is useful for proper clinical interpretation.

Thus, the information provided to the automated interpretation system may include:

(1) ancillary data, such as the patient's clinical history, such as the presence of a breast lump, the history of a transient ischemic attack ["TIA"], or a history of atrial fibrillation, the patient's age, pertinent laboratory findings, quantifiable visual functions, such as visual acuity, or visual field indices, and pertinent physical findings, such as neurological deficits, a breast lump, blood in the feces, or limitation in motion of a joint;

(2) reliability indices, such as patient cooperation, or movement, or absence of movement, during the MRI, CT or the ultrasound testing procedure;

(3) visual field indices, if known, such as average deviation of sensitivity at each test location from age-adjusted normal population values, the index of the degree of irregularity of visual field sensitivity about the normal slope, and sensitivity analysis of clusters of points;

(4) results of point-by-point comparison of test results with age-matched normal population values; and

(5) other available tests.

The implementation may be in the form of a single-level system or a hierarchical system. In the single-level system, all the input data which are deemed relevant for the interpretation task are inputted and processed simultaneously. In the hierarchical system, different input data types are modeled by dedicated separate sub-systems, and their outputs are subsequently fused through a suitable computational architecture, such as a neural network, to produce the final classification result.

The automatic interpretation system can consist of the following models:

(1) clustering/data reduction module, which may employ singular value decomposition, principal component analysis (PCA), learning vector quantization, or other clustering or data size reduction methods;

(2) data normalization module, which performs amplitude normalization of the data presented;

(3) data classification module, which performs pattern recognition, classification, and quantification of the MRI, CT or ultrasound test data through non-linear or linear mapping. This function may be accomplished through the use of multilayer perceptron neural network and other neural network architectures, or through non-linear,

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multivariate, or linear regression of the data, or by multivariate statistical classifiers or discriminators such as Bayesian classifiers; and,

(4) output module, creating a graphical representation of the MRI, CT or ultrasound test data, such as gray scale of color-coded plots, with superimposed identification of the regions that the system classified as abnormal.

The automatic interpretation system is an expert system automatically trained on a set of empirical, semi-empirical, and/or simulated data. The construction of a proper training database is essential for achieving good performance of the interpretation system, with good sensitivity and specificity.

The training database may contain all, or any, of the following types of MRI, CT or ultrasound data:

(1) empirical data, i.e., data obtained for patients with normal and abnormal MRI, CT or ultrasound scans;

(2) semi-empirical data, i.e., data obtained by modification of the empirical data, as described above, by:

(a) emphasizing or de-emphasizing certain aspects of the MRI, CT or ultrasound test to bring out the characteristic features of certain diseased states;

(b) adding noise or measurement uncertainty components which may be associated with a real MRI, CT or ultrasound imaging examination; and,

(c) any other modification of the MRI, CT or ultrasound imaging data and their associated classification; and,

(3) simulated data; i.e., data which are constructed to simulate the real-world results of MRI, CT or ultrasound scans for both normal and abnormal MRI, CT or ultrasound tests.

The present invention utilizes telemedicine for supplying, testing, measuring, quantifying, and autointerpreting MRI, CT or ultrasound scans. It facilitates monitoring the performance of the MRI, CT or ultrasound tests in real time, and provision is made for providing real time active feedback stimuli to the patient, such as encouragement, such as when the MRI, CT or ultrasound test is prolonged, or other verbal or nonverbal feedback stimuli.

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The content of the software is dictated by the need to provide technically acceptable protocols for MRI, CT or ultrasound testing in order to obtain the highest quality MRI, CT or ultrasound scan and, hence, the best possible autointerpretation test results.

While the particular invention as herein shown and disclosed in detail is fully capable of obtaining the objects and providing the advantages hereinbefore stated, it is to be understood that this disclosure is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended other than as described in the appended claims.

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CLAIMS

We claim:

1. A diagnostic imaging system comprising:

an imaging device for collecting diagnostic image data of a patient at a local site;

a computer located at a site remote from said local site, said remote computer being programmed to receive said image data, and to provide diagnostic information to a patient;

an automatically-trained expert system at said remote site connected to said remote computer for receiving said image data, for instantaneously interpreting said image data, and for providing interpretation of said image data to said remote computer; and

a data transmission system between said local and remote sites.

2. A diagnostic imaging system as recited in claim 1, wherein said remote automatically-trained expert system comprises a neural network.

3. A diagnostic imaging system as recited in claim 2, wherein said neural network is incorporated within said computer.

4. A diagnostic imaging system as recited in claim 1, wherein said data transmission system between local and remote sites comprises the Internet.

5. A diagnostic imaging system as recited in claim 1, wherein said imaging device comprises a magnetic resonance imaging device.

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6. A diagnostic imaging system as recited in claim 1, wherein said imaging device comprises a computed tomography imaging device.

7. A diagnostic imaging system as recited in claim 1, wherein said imaging device comprises an ultrasound imaging device.

8. A diagnostic imaging system comprising:

a plurality of local imaging devices for collecting diagnostic image data of patients at a plurality of local testing sites;

a computer located at a site remote from said local sites, said remote computer being programmed to receive said image data, and to provide diagnostic information to patients at said local sites;

a neural network at said remote site for receiving said image data, for instantaneously interpreting said image data, and for providing interpretation of said image data to said remote computer; and

a data transmission system between said local testing sites and said remote site.

9. A diagnostic imaging system as recited in claim 8, wherein said neural network is incorporated within said remote computer.

10. A diagnostic imaging system as recited in claim 8, wherein said data transmission system between local and remote sites comprises the Internet.

11. A diagnostic imaging system as recited in claim 8, wherein said local imaging devices comprise magnetic resonance imaging devices.

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12. A diagnostic imaging system as recited in claim 8, wherein said local imaging devices comprise computed tomography imaging devices.

13. A diagnostic imaging system as recited in claim 8, wherein said local imaging devices comprise ultrasound imaging devices.

14. A method for performing diagnostic imaging, said method comprising:

providing a diagnostic imaging device at a local site, a computer at a site remote from said local site, an autointerpretation system at said remote site, and a data transmission system between local and remote sites;

collecting diagnostic image data of a patient at a local site;

transmitting said image data from said local site to said computer at said remote site, via said data transmission system;

providing said image data to said remote autointerpretation system;

instantaneously interpreting said image data with said remote autointerpretation system;

providing interpretation of said image data to said remote computer; and

providing diagnostic information to a patient at said local site with said remote computer, via said data transmission system.

15. A method for performing diagnostic imaging as recited in claim 14, wherein said remote computer is connectable to said diagnostic imaging system via the Internet.

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16. A method for performing diagnostic imaging as recited in claim 14, wherein;

said diagnostic imaging device comprises a magnetic resonance imaging device; and

said diagnostic image data collected is magnetic resonance image data.

17. A method for performing diagnostic imaging as recited in claim 14, wherein;

said diagnostic imaging device comprises a computed tomography imaging device; and

said diagnostic image data collected is computed tomography data.

18. A method for performing diagnostic imaging as recited in claim 14, wherein;

said diagnostic imaging device comprises an ultrasound imaging device, and

said diagnostic image data collected is ultrasound data.

19. A method for performing diagnostic imaging of a plurality of patients, comprising:

collecting a set of diagnostic image data for each of a plurality of patients;

transmitting said sets of image data to a central computer via the Internet; and

instantaneously interpreting said sets of image data with a central neural network.

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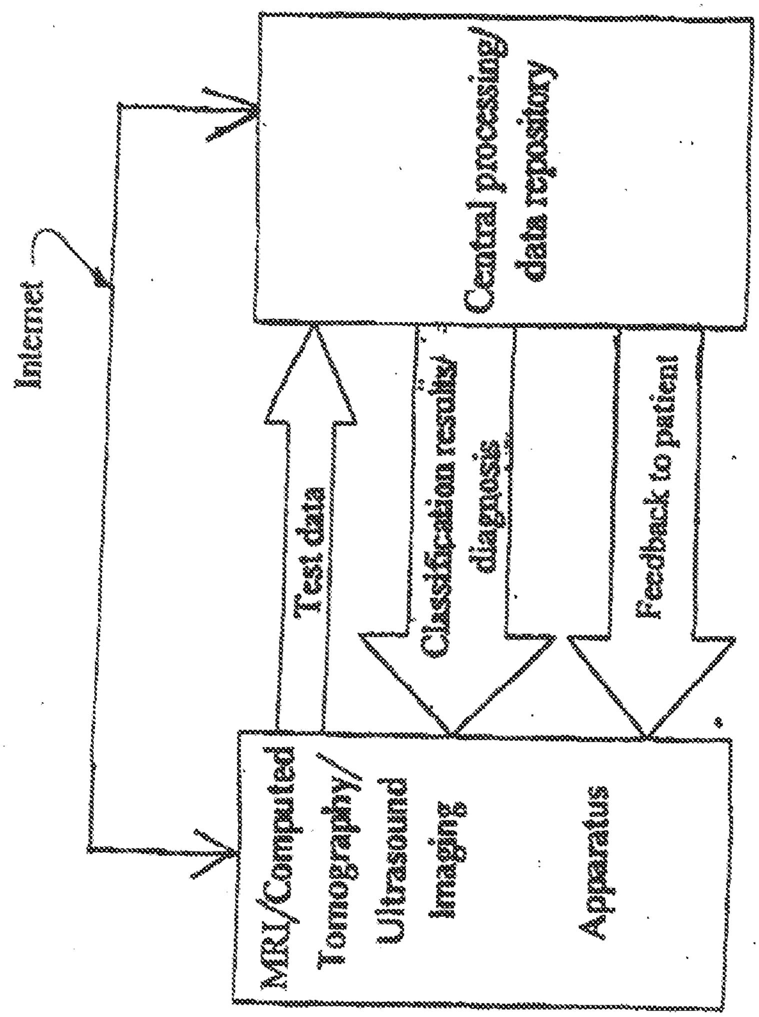
Internet
Central processing/
data repository
Test data
Classification results/
diagnosis
Feedback to patient
MRI/Computed
Tomography/
Ultrasound
Imaging
Apparatus

FIGURE 1

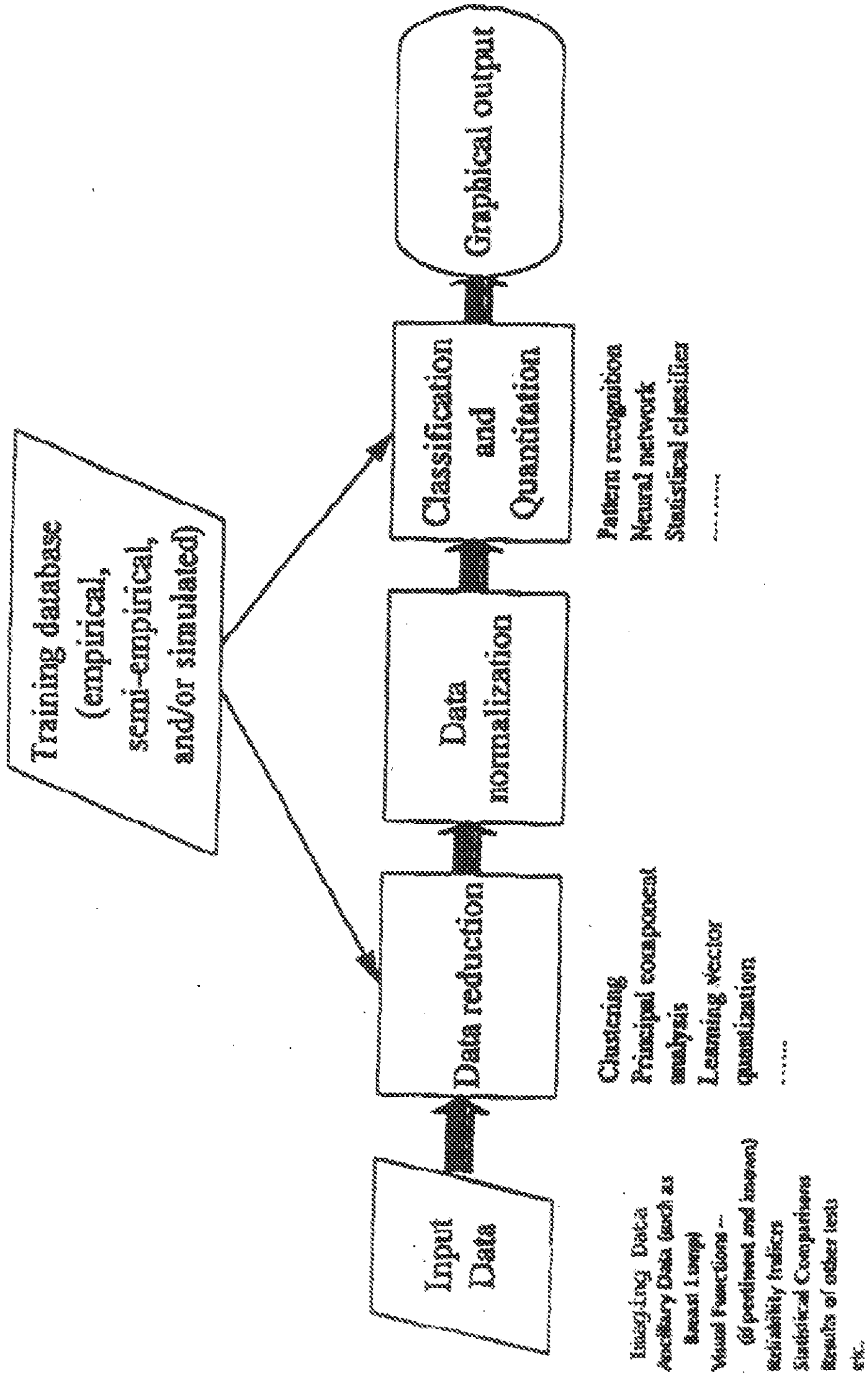

FIGURE 2

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